Paper No. 902530
AN ASAE MEETING
PRESENTATION

DESIGN AND INSTALLATION OF A DRIP IRRIGATION SYSTEM FOR RESEARCH PURPOSES

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Written for presentation at the
1990 International Winter Meeting
sponsored by
THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Hyatt Regency Chicago
Chicago, Illinois
December 18-21, 1990

SUMMARY:

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KEYWORDS:
microirrigation, trickle irrigation, irrigation, controlled traffic

ASAE
American
Society
of Agricultural
Engineers

St. Joseph, MI 49085-9659 USA

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ABSTRACT

A 5.2 ha (12.8 acre), buried-line, drip irrigation system was designed and installed to conduct engineering and agronomic research. The system consists of 121 individually controlled plot areas. Criteria for designing a large, multiple-plot, drip irrigation system for research use differ greatly from those used for a commercial farm irrigation system. There are very few descriptions in the literature of construction of large drip irrigation systems for research. The paper describes the approach taken at a site in western Kansas.

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Contribution No. 91-254-J from the Kansas Agricultural Experiment Station.

This material is based upon work supported by the U.S. Department of Agriculture Cooperative State Research Service under Agreement No. 89-COOP-1-4927.

INTRODUCTION

Water is the most limiting factor in crop production in western Kansas. Although irrigation is used on only a small percentage of the land area, it has a significant effect on total crop production and economic stabilization of the region. Groundwater declines resulting in large reductions in irrigated areas could cause severe social and economic hardship for the people of Kansas. Drip irrigation has been shown to decrease irrigation water use, while maintaining high yields and crop quality. However, very little research has been done in the Central Great Plains using the system on crops such as field corn because of the high investment costs. The Kansas Agricultural Experiment Station (KAES) recognizes that water resource constraints and changing economics may dictate a move towards advanced irrigation technologies such as drip irrigation.

In the fall of 1988, the KAES funded a project entitled "Sustaining Irrigated Agriculture in Kansas with Drip Irrigation" to be conducted at the KSU Northwest Research-Extension Center at Colby, Kansas. No preexisting drip irrigation system was available at the Center, resulting in an unique opportunity to design and construct a system expressly for research use. Additional funding became available from the USDA Cooperative State Research Service in the fall of 1989 to expand the system at Colby and to develop a 4 ha (10 acre) system at the KSU Southwest Research-Extension Center at Garden City, Kansas. This report will deal primarily with the development of a 5.2 ha (12.8 acre) buried-line drip irrigation system at Colby. However, many of the design details are identical for both sites.

Hydraulic design information for drip irrigation systems can be obtained from several sources. Most of the major manufacturers of dripline supply design manuals for their equipment. Howell et al. (1983) discuss many of the basic considerations for designing farm drip irrigation systems. A book edited by Nakayama and Bucks (1986) covers the hydraulic design of drip irrigation systems. However, there are few, if any, sources in the literature of step-by-step information on design and construction procedures for a complete drip irrigation system to be utilized for research. For an installation used for engineering and agronomic research, it is often desirable to have a large quantity of small, uniform plots that have individual controls and monitoring devices. This report will outline how a large multiple plot system was designed and installed at Colby and will concentrate on overall design considerations rather than such specifics as hydraulic design.

SITE SELECTION

Site selection was an important consideration in meeting the functional requirements of the project, while still keeping within the budget. The soil is a Keith silt loam typical of many of the soils in western Kansas with a land slope less than 1 percent, which enhances water application uniformity. The well site is well-drained in all directions, which helps to make it an environmentally sound location.

The well site is adjacent to the corners of the substudies to minimize installation costs (Figure 1), primarily in reductions in the length and size of PVC plastic mainlines, the amount of electrical wire, and the amount of trenching. Should a water line break in one of the substudies, this design generally will allow that portion of the system to be isolated from the rest of the system by means of a control valve at the pumpstand. This permits continued irrigation of other substudies, while the problem is being repaired.

The availability of three-phase electrical power within 15 m (50 ft) of the well site was of significant economic importance because of the high cost of extending three-phase power lines. The well site is within 150 m (500 ft) of existing telephone lines. A county road within 200 m (500 ft) helps to make the site accessible under adverse weather conditions.

CONTROL BUILDING

A 3.7 x 4.9 m (12 x 16 ft) control building was constructed at the well site in the fall of 1988. The wood frame construction allowed easy placement of electrical outlets, plumbing, cabinets, and control panels. For security purposes, the building has no windows and is equipped with a steel-clad door with a dead bolt.

The building has air conditioning, but heating is limited to a 1500 watt utility heater. A sink provides water availability when the well is pumping. A phone line was installed to provide communication capabilities. An injection unit for injecting chlorine bleach into the irrigation system is located within the building. The chlorine bleach reduces the potential for algal and bacterial growth in the driplines. Cabinet storage space for maintenance and chlorination supplies is provided in the building. A desk and computer area are available for data analysis, while an individual is monitoring an irrigation event.

Electricity is provided by a 5 KVA dry transformer that transforms the three-phase service to the pump to single-phase power for the building. The transformer provides enough power for a small air conditioner, irrigation plot transformers, computer, chlorine injection unit, small refrigerator, and lighting. Use of the dry transformer eliminates the need for a separate single-phase service and the accompanying connect costs.

Irrigation is controlled by a control panel that allows the switching on and off of solenoid valves that regulate flow to each plot. Irrigation amounts applied to each plot can be monitored through remote flow accumulator registers located within the building.

The building was constructed 3 m (10 ft) from the proposed well site, to allow for easy injection of chlorine bleach into the pumpstand from within the building. This minimum distance, was determined from consultation with a well driller to allow the drilling of the well or any future pump-pulling operation without any hindrance.

WELL AND PUMP

The well was drilled under a "performance specification" bid. This type of bid was written in lieu of specification of the actual size bore hole, well screen, gravel pack, specific development techniques, and pump. The performance specification for this well was a "sand-free well" that would deliver at least 6.3 l/s (100 gpm) at 240 kPa (35 psi) at the ground surface. A "sand-free well" was defined as less than 8 ppm of sand. The well was specified to be drilled with a minimum 30 cm (12 in) bore hole to shale at a depth of approximately 75 m (270 ft) and cased with 20 cm (8 in) or larger diameter PVC plastic pipe. The well screen was specified to be 18 m (60 ft) in length and extend to the bottom of the well. It was specified that one of the following development procedures be used; air development and/or water jetting or surge blocking. Additional procedures the bidder might wish to consider in meeting the performance specification were suggested in the bid but not required.

A performance specification bid greatly reduced the amount of detail required in the request for bids. Many of the actual specifications cannot be made without drilling a test hole. For a small well, it may be more expedient and less expensive to drill the well in one operation. This type of bid does place more burden on the bidder because payment is contingent on meeting the performance specification. However, most well drillers in the area have a good understanding of the underlying formations because of past experience. In some cases, the performance specification bid may allow the bidder more flexibility in using the well drilling equipment and development techniques with which the bidder feels most comfortable.

The well was equipped with a five-stage 15 cm (6 in) electric, submersible pump. The electric pump allows for more convenient operation of the system and may be incorporated into future automation designs.

The pump stand includes a Kansas-approved chemigation check valve to prevent backflow down the well casing. A pressure relief valve located upstream from the check valve vents excess water down the well casing, to alleviate pressure increases which can occur as individual plots are shut off. This is uncontaminated water prior to entering the check valve. A flowmeter measures total water pumped from the well to the plot areas. The water is filtered with a 200-mesh screen to remove any impurities. The filter is rated at twice the flow capacity of the well. Pressure gages are used to measure the line pressure and also the pressure drop across the filter. A pressure drop of 35 kPa (5 psi) indicates that the filter needs to be flushed or cleaned. An injection point for chlorine bleach is located downstream from the flowmeter but upstream of the filter. This location helps to protect the flowmeter from corrosion and to keep the filter clean. Flow to the three general plot areas is controlled by manual gate valves located on a distribution manifold following the filter.

All above-ground, white, PVC plastic was painted an opaque color to prevent algal bloom from the small amount of sunlight that passes through the PVC. Galvanized steel and brass fittings were avoided as much as possible after flow leaves the filter, because they may corrode and cause plugging of the driplines.

LAND PREPARATION

The standard drip irrigation configuration selected was one dripline centered between every two rows of corn. This allows for a 1.52 m (5 ft) dripline spacing with corn rows no more than 38 cm (15 in) from the nearest dripline. Permanent 1.52 m (5 ft) beds were constructed in the fall prior to dripline installation in the spring to help ensure that the corn rows remain close to this spacing. The land area was chiseled to a depth of 35 cm (14 in) and then double-disked in alternate directions to create 10-15 cm (4-6 in) depth of loose well-granulated soil. The area was then bedded in 1.52 m (5 ft) wide, triangular-shaped beds with a peak approximately 35 cm (14 in) above the furrow. In essence, the bedding process moved the 10-15 cm (4-6 in) of loose soil from the furrow area and laid it over another 10-15 cm (4-6 in) of loose soil. This created a well-fractured bed in which the dripline was installed the following spring.

Wheel traffic is restricted to the furrow area to prevent compaction of the soil over the dripline. This should minimize wicking of soil water to the soil surface. Drier soil surfaces should limit evaporation losses and restrict weed seed germination. The peaked bed was flattened slightly with a springtooth harrow in the spring to allow corn planting at the edges of the flattened top (Figure 2).

DRIPLINE SELECTION

Selection of a dripline capacity was influenced by the assumptions that 1) most irrigators would want to handle a drip irrigation system in 12 or 24 hour sets, similar to a furrow irrigation system and 2) most irrigators would initially not want the additional expense of automating the system. A dripline capacity of 1.86 l/hr-m (0.25 gpm/100 ft) on a 1.52 m (5 ft) spacing applies a gross of 29.3 mm (1.15 in) in a 24-hour event. In western Kansas, a typical land area developed for irrigation is a square block of 64.8 ha (160 acre). Assuming a 4-day cycle, a well capacity of 55 l/s (871 gpm) is needed to irrigate the required number of subareas within the 64.8 ha (160 acre) block. This well capacity is certainly within the reach of many irrigation systems in western Kansas. Of course, larger or smaller well capacities can be accommodated by changing irrigated land area. However, it seemed appropriate to simulate typical system capacity for the region. Changing the length of an irrigation event does not change the required well capacity, only the number of days between cycles.

The dripline selected for use in this project, manufactured by Chapin Watermatics Inc[1] is called Turbulent Twin Wall IV and has a nominal emitter spacing of 30 cm (12 in) and a flowrate of 1.86 l/hr-m (0.25 gpm/100 ft) at the design pressure of 69 kPa (10 psi). This corresponds to a gross irrigation rate of 1.22 mm/hr (0.048 in/hr) for the standard 1.52 m (5 ft) dripline spacing.

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[1] The mention of tradenames or commercial products does not constitute their endorsement or recommendation by the authors, the Kansas Agricultural Experiment Station, or the USDA Cooperative State Research Service.

DRIPLINE INSTALLATION

A single, parabolic chisel shank was used to "plow" in the dripline tubing in 1989. A reversing tube was added to the shank to guide and reverse the direction of the dripline into the chisel slot. The dripline was installed with the emitters facing up. A heavy iron bar was used to level soil behind the shank.

The reversing tube was made by sandwiching two curved pieces of nominal 2.5 cm (1 in) wide flat iron between two iron plates. The flat dripline is slightly less than 2.5 cm (1 in) wide. The close tolerance occasionally caused problems because dust would settle in the reversing tube during the "plowing in" of the dripline. Problems ranged from a slight drag on the dripline that caused minor stretching to the complete tearing of the dripline. Though these problems only occurred occasionally, they are reasons for concern when trying to install driplines for a uniform research installation. Occasionally, the close tolerance of the reversing tube would result in a slight nick in the dripline. This would show up as a leak during irrigation requiring repair.

The reversing tube was redesigned in 1990 (Figure 3), because of these problems. It was also desirable to construct a three-row unit so that more driplines could be installed at once. Rather than use the nominal 2.5 cm (1 in) wide flat iron that is readily available it was decided to have 2.86 cm (1.125 in) strips of flat iron sheared from larger stock. These new reversing tubes had greater clearance and worked much better than the one used in 1989. Only one nick occurred during the installation of 7 ha (17 acre) of drip irrigation in 1990.

The driplines were installed approximately 40 cm (16 in) below the final ground surface. In a normal drip irrigation event at Colby, there is seldom any wetting of the soil surface when the dripline is buried at 40 cm (16 in) in this permanent bed situation. In western Kansas, irrigation is typically not needed for germination and establishment of summer row crops. In those years when such irrigation is needed, upward soil water movement can be enhanced by irrigating for an extended period of time, perhaps as long as a week.

In 1989, the driplines were secured at the field margins during installation with a screwdriver forced through the center of the dripline. Although this worked fairly well, the dripline would occasionally pull loose. In 1990, small self-clenching belt buckles and straps connected to rods pushed into the ground were used to hold the dripline. These were quick to install and held the dripline firmly.

Another recurring problem during installation was that the cardboard spools used to hold the dripline did not hold the dripline firmly along the edges. Occasionally, the dripline would slide between the cardboard cover and the remaining roll and fall down to the center axis of the spool. This would pinch the dripline and cause it to break. This problem was solved by having an individual ride along on the chisel implement as the dripline was being installed and guide the dripline off the roll. Some have suggested sandwiching the spool between plywood plates to alleviate the problem. However, sometimes the dripline as it comes from the factory is pinched between the cardboard and the remaining roll. Sandwiching the spool would only make this problem worse. Although the dripline was installed at a travel speed of only 3.5 kph (2 mph), it was undesirable from a safety standpoint, to have riders on the chisel. This also increased labor requirements. Clearly, this is a problem the manufacturers should address, if deep, buried-line, drip irrigation is to have a place in large production fields.

As the chisel passes through the soil, the slot above the dripline may or may not fully close. A drag bar should be installed behind the shanks to ensure that it fully closes. This keeps rodents or insects from traveling down the slot and damaging the dripline.

Some of the distributors of dripline have suggested that a long period of time between dripline installation and the initial developmental irrigation should be avoided. Irrigation soon after installation ensures that a "mole hole" is developed by the swollen water-laden tube before heavy compaction occurs. Heavy precipitation may cause a collapse of the bridged soil structure above the dripline. If this happens, it may be difficult or impossible to properly develop the driplines. In the 1990 installation, the 7 ha (17 acre) of dripline was installed in mid-March, approximately 3-4 weeks before the initial irrigation. However, in the Central Great Plains, intense rainstorms of long duration are not common at this time of year. It is desirable to install the system during the drier part of the year and also when it is warm enough to avoid overnight freezing of the system that may be in various stages of completion and unprotected from possible damage.

Rubber or plastic hoses to initially guide the dripline into the reversing tube should be avoided, based on observations of a farmer installing driplines. The friction between the rubber or plastic hose and the dripline can cause inconsistent slippage between the two surfaces. Additionally, the reversing tube may become gummed up from the abraded particles caused by the friction. Lubricants should not be put in the reversing tube.

DRIPLINE PREPARATION FOR TRENCHING

There is a short transition length of about 2-3 m (6-10 ft) from where the chisel begins to install the dripline to where the dripline reaches the desired depth. All the connections should be made at the same depth for buried submains. Consequently, this transition length is of no use. A research installation should have all the driplines for a submain with identical lengths, so that water application amounts are easily computed. This can be accomplished by stretching a string between the field edges perpendicular to the driplines and then cutting them below the soil surface. The driplines in this study were cut by pushing a well-sharpened serrated sickle mower section straight down through the dripline. This was done soon after installation, while the chisel slot was still soft compared to the bed, which makes the dripline easily located at the bottom of the slot. The short transition lengths were removed and discarded after cutting to prevent rodents and insects from following the exposed dripline down into the plot area.

The dripline should definitely be cut before trenching. If it is not cut, the trencher chain often will grab the dripline, stretch it and occasionally cause it to break somewhere away from the trench. The dripline can be cut so that 5-10 cm (2-4 in) is exposed after trenching.

Generally, this short exposed section will be feathered by the chain rather than grabbed and stretched.

The dripline installation process greatly loosens the soil. It is desirable to compact the PVC main and submain trench lines so that the trench walls will retain integrity during the lengthy process of installing the mainlines and connecting the submains to the driplines. The soil should be leveled at the field margin so that the trencher can operate on a level surface. The trench line can be compacted with a medium-sized rubber-tired tractor.

TRENCHING AND PIPELINE INSTALLATION

The mainline and submain were both placed in the same trench to facilitate installation. A 20-25 cm (8-10 in) wide trench allowed enough room to make the necessary connections at the dripline depth of 40 cm (16 in). In the two substudies installed in 1989, the mainline was laid to grade at a depth of 60 cm (24 in). The pipelines were graded to a drainage ditch to allow complete drainage to avoid freezing in the winter. Laying these nominal 5 and 7.6 cm (2 and 3 in) ID PVC plastic pipelines to grade proved to be a very time consuming task because of the low and variable ground slopes, ranging from 0 to 1 percent.

The submain lies in the trench at a depth of 40 cm (16 in) to coincide with the depth of the driplines. Each 19 mm (0.75 in) ID PVC plastic submain services one plot and was either 4.6 m (15 ft) for a 6 m (20 ft) wide plot or 7.6 m (25 ft) for a 9 m (30 ft) wide plot. The water rises from the mainline through a 19 mm (0.75 in) ID reinforced plastic hose to a control assembly that is connected to the submain. Each of these assemblies is situated in a manhole constructed from a 57 l (15 gal) plastic or steel barrel buried to the submain depth.

In 1990, the 5, 7.6, and 10 cm (2, 3 and 4 in) ID PVC plastic mainlines were buried at a depth of 80 cm (32 in), which is below frostline for the area. The mainline was allowed to follow the natural grade of the soil surface, which greatly decreased the installation time. Although the plastic hose rising from the mainline was longer, the friction loss is small for the flowrates of the plots. Small differences in friction losses in the mainline are of no consequence, because flow is controlled at a later point in the system.

The driplines were exposed to give a larger workspace for making connections by caving off the trench wall in a semicircle approximately 20 cm (8 in) in radius.

The mainlines were terminated at the end of the trenchline with temporary standpipes open to the atmosphere. Installation debris was flushed from the mainlines through the temporary standpipes prior to connecting the mainlines to the submains. The trench was backfilled with soil and water-packed to approximately 5 cm (2 in) below the depth of the driplines.

A trench was also dug at the tail end of the driplines for a terminal submain or flushline to be connected to the driplines. It was approximately 60 cm (24 in) in depth to allow for measurement of the free flow from individual driplines. The laying of the flushline is one of the last processes and will be discussed in a later section.

CONTROL ASSEMBLY CONSTRUCTION

The control assemblies that transfer water from the mainline to the submain were constructed in the laboratory prior to field installation. Each assembly consisted of a 24 volt electric solenoid valve, a flow accumulator with an electrical pulse generator for remote readout, a pressure regulator, a manual gate valve, a pressure gage, an access point, and connection fittings (Figure 4).

A 19 mm (0.75 in) Hardie 700 solenoid valve[1] was used in the control assembly because of its small size which makes it advantageous in the limited workspace of the manhole.

A Kent PSM-190 plastic flow accumulator[1] [15.8 mm chamber x 12.7 mm (0.625 x 0.5 in) flowmeter coupling thread] was used in the control assembly. This meter was selected because of its low weight [850 gm (1.9 lb)] as compared to a brass valve [1420 gm (3.1 lb)]. The main parts of the assembly were mounted in a cantilever position from the connection fittings, so weight was an important consideration. The plastic flow accumulator also presents less potential for corrosion when chemicals are injected into the system. The 12.7 mm (0.625 in) flowmeter coupling thread corresponds approximately to the 19 mm (0.75 in) male imperial pipe thread. However, there is no thread taper on the flowmeter coupling thread. A nonleaking fit could be made by wrapping an extra layer of teflon tape around the threads. This type of meter is typically used in municipal residential water lines and has accuracy to +/- 1.5%.

The water pressure is lowered with a pressure regulator to 138 kPa (20 psi). This is necessary because the mainline pressure fluctuates as irrigation for certain plots is started and stopped. The pressure regulator will "standardize" the pressure to approximately 138 kPa (20 psi) as long as the mainline pressure is over approximately 170 kPa (25 psi). Senninger pressure regulators[1] were used in the assemblies because of their high regulating accuracy +/- 6%. They also have a very low hysteresis, as documented by von Bernuth and Baird (1990). In this particular application, small deviations in the standard set pressure between regulators are tolerable because the dripline is operated far below the standard pressure. However, low hysteresis is critical because of the fluctuating mainline pressure. The flowrate as calculated manually during a small portion of the irrigation event is used to project when flow to the plot needs to be shut off. Standardizing the pressure at 138 kPa (20 psi) instead of the 69 kPa (10 psi) at which the system is usually operated, permits a higher flowrate to be used during periodic flushing.

The manual gate valve is used to reduce the pressure from the "standardized" pressure to the operating pressure, 69 kPa (10 psi). Once it was set at the beginning of the season, it rarely needed adjustment.

The pressure gage [0-207 kPa (0-30 psi) with accuracy +/- 2% of full scale] is used to set the operating pressure of the submain. A comparison of the actual flowrate and pressure to the design flowrate and pressure can indicate if the submain is performing adequately. A high flow at the design pressure may indicate a leak in the driplines. A low flow at the design

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pressure may indicate clogging of one or more of the driplines. These utility grade gauges [5 cm (2 in) face] are best used to compare operating conditions between events rather than for exact pressure/flow measurements.

An access point provided on the control assembly can be used to tap in a high quality pressure gage for developing pressure/flow relationships for the submain and driplines. This access point also serves as an injection point at the plot level for fertilizer. In a replicated fertilizer study, the ability to inject fertilizer at the plot rather than in the mainline is important.

The control assembly is connected to the mainline plastic hose and a rigid PVC plastic riser from the submain with male and female garden hose connections. This allows for removal of the assembly in the winter to avoid freezing. The mainline and submain are capped after removal of the assembly to avoid dirt intrusion into the pipelines. The mainline uses a plastic hose instead of a rigid riser to allow a small amount of construction tolerance in making the connections of the control assembly to the submain. PVC plastic female, swivel hose connectors and nylon male hose connectors are used instead of brass. In the limited work space of the manhole, it is easy to cross-thread the connections. The PVC female mates easier to the male nylon hose thread than to a brass fitting. The PVC threads are harder than the nylon threads, so should a fitting get cross-threaded, the nylon fitting is most likely to have the ruined threads. This is desirable because the nylon connector is cheaper and is generally easier to replace.

An automotive-type, four-pole, electrical connection was used to connect the solenoid and flow accumulator to the electrical cables running to the building. This type of connector was used to allow easy removal of the control assembly.

SUBMAIN CONSTRUCTION

The submains were constructed in the laboratory from 19 mm (0.75 in) ID PVC plastic. In the standard configuration, they are 4.6 m (15 ft) wide for a 6 m (20 ft) plot with four dripline outlets located 1.52 m (5 ft) apart. A 20 cm (8 in) long riser for connection to the control assembly is located 1.5 m (5 ft) from the right end as the submain would face the plot area (Figure 5). The riser is placed off center, so the manhole is situated at the center of a bed rather than in the furrow to avoid traffic from farm implements. The submain is not symmetrical with respect to the four outlets. However, the friction loss in the submain is low, and the differences in flow between outlets are negligible. In 1990, reducing tees and elbows [13 x 19 mm (0.5 x 0.75 in)] were used for the outlets. Compression adapters that glue into the reducing tees and elbows were used to connect to the dripline supply tube.

The terminal submains or flushlines are similar to the regular submains with the exceptions that the riser consists of a 35 cm (14 in) long flexible plastic hose and is installed 1.5 m (5 ft) from the left end of the submain as it faces the plot. Each flushline is connected back to the four driplines from the submain on the head end of the field. This allows a central flushing point for the plot and also allows some pressure equalization between the driplines. The flushline is fitted with a manual ball valve for flushing. Buried low pressure drains on the submains were not used because of the uncertainty of their consistent operation over a period of years. Improper sealing of the drains could be a source of experimental error in precise water use studies. Flushing has generally been done at the beginning and end of the season. The quality of the water source is high, and the water is low in iron and sulfur, so not much flushing is required.

MANHOLE AND SUBMAIN INSTALLATION

After the trenches were backfilled above the mainline and water-packed to the desired depth, the manholes and submains were set. The submains were fitted with supply tubes and driplock connectors to make the final assembly to the driplines. In many drip irrigation systems, the supply tube serves as the flow regulator. However, in this system, the control assembly is used to regulate flow. A 8.9 mm (0.35 in) ID supply tube, 20 cm (8 in) long was used for all driplines in the 1990 study. The driplock connector makes the final connection of the supply tube to the dripline. After the submains were connected, they were laid loosely in the trench until placed at grade using sand backfill.

The plastic hose from the mainline was cut to the desired length based on the height of the control assembly, submain, and manhole with respect to bed height. A hose barb x male hose thread fitting is inserted into the hose to allow for connection to the control assembly.

The electrical cable is strung through the appropriate manholes with an approximately 90 cm (3 ft) loop brought up in each manhole for the necessary electrical connections and splices. A single common ground can be used to tie all the flow accumulators together. Similarly, a single ground can be used for the 24-volt AC solenoid valves. However, to reduce installation time, 18-gage, 12-conductor, direct-burial, control cable was used in the trench. This allowed 5 plots to be wired with a single cable (5 flow accumulators, 5 solenoid valves, and 2 separate grounds). This cable could then travel on to the control building without entering the other manholes.

The manhole was then placed over the mainline hose and the submain riser. The control assembly was connected to the mainline and submain, so that proper reference heights could be maintained during the sanding process.

The irrigation water was then introduced into the system to check for leaks in the driplock connections to the driplines. Irrigation can be performed by electrically powering the solenoid valves which requires completion of the electrical wiring at this point or by manually opening the solenoid valves.

The manhole and submain were then leveled and preliminarily set with sand. Sand was used instead of soil to help ensure that a stable level bed for the submain could be maintained. Care was taken to avoid kinking of the supply tube or dripline. Water pressure helps avoid the pinching off of the flow.

The 19 mm (0.75 in) ID submain is only 40 cm (16 in) below the soil surface so it must be level for proper drainage to avoid overwinter freezeup. A leveler for the submains was constructed by attaching alligator clamps to rods extended down from a rigid aluminum tube (Figure 6). The 5 alligator clamps are evenly attached to the submain causing it to remain parallel to the aluminum tube. A continuous water level tube was used to compare the relative elevations of the ends of the aluminum tube. In practice, one end of the submain was sanded in at the desired depth, and the rest of the submain was then leveled accordingly. The manhole was also sanded in to hold it in place. Only 5-10 cm (2-4 in) of sand was placed over the submains until the driplines were fully developed. The submain leveler was removed from the submain by releasing the alligator clamps.

DRIPLINE DEVELOPMENT

After preliminary sanding of the submains and manholes, the driplines were ready to be developed. The driplines were checked in the flushline trench to make sure each was flowing. Gross visible differences in flow among the driplines of a submain usually indicated a kinked supply tube or possibly a compacted dripline at the edge of the trench wall. Corrections for gross visible differences were made at this time. The free flow also allows impurities that entered the system during installation to be flushed. Individual driplines at the flushline trench were then temporarily sealed with medium-sized binder clips available from office supply stores. The driplines were then allowed to develop using approximately 69 kPa (10 psi) of pressure for at least 12 hours. Ideally, during this period of time, a mole hole will develop for the entire length of each dripline. Gross leaks in the field will also show up and can be repaired.

After the driplines had developed a mole hole, the binder clips were removed. The flows from individual driplines were caught for 20 seconds in plastic 4 l (4 qt) pitchers and measured in a graduated cylinder. Although the exposed driplines vary in shape under free flow and cannot be considered identical orifices, the flows among the 4 driplines from a submain can be compared to highlight problems. In this installation, the free flows among the driplines of a single submain generally varied less than 10%. Larger variations were usually associated with a kinked dripline or supply tube, and any problems were corrected. When the flows were remeasured, the variation was usually reduced. However, sometimes the previously pinched dripline would require more time to develop a mole hole.

The flow through the control assembly also can be compared to the cumulative free flow of the exposed driplines. This comparison should be made only by recognizing that the driplines are also leaking a small amount of water down their entire length during the process. Gross differences may indicate a yet undiscovered leak in the dripline, and efforts should be made to locate and fix it.

FLUSHLINE INSTALLATION

After full development of the driplines, the flushline trench was backfilled and water-packed to approximately 5 cm (2 in) below the driplines. The flushline was then attached to the driplines, leveled, and sanded-in, similar to the procedure used for the submains at the head end of the field.

TRENCH BACKFILLING

The submain and flushline trenches were then backfilled to the soil surface. Care was taken to avoid shifting of the submain and manhole because a kinked line at this point cannot be easily diagnosed and found. After some natural settling following rainfall or water-packing, additional soil was added to the trench. The trench and the area around the manhole were brought up to approximately the bed height, to eliminate clearance problems for tractor and implements entering or leaving the field. This may be done later, after settling has occurred. Careful grading of soil with a tractor and blade plus some hand work left a smooth firm surface for an all-terrain vehicle (ATV) to pass alongside the manholes for periodic monitoring during the irrigation season.

OPERATION AND AUTOMATION OPPORTUNITIES

At the design pressure 69 kPa (10 psi) and the standard 1.52 m (5 ft) dripline spacing, the system applies 29.3 mm (1.15 in) in a 24-hour period. A climatic-based water budget was used to calculate irrigation needs. When the cumulative deficit reached 20-30 mm (0.75-1.25 in), the soil profile was recharged. To apply a given amount to a plot area, the flowrate was calculated for a 10-60 minute section of the irrigation event. A shutoff time was projected using this calculated flowrate and the amount of water remaining to be applied. This procedure has worked well with accurate projections usually within 5 minutes for events as long as 24 hours. Small deviations in applied amounts were corrected at the next irrigation.

A pilot project for automating a portion of the irrigation system was installed in the middle of the 1990 season. This device was custom built to meet the system's needs by a commercial enterprise.

Several steps are required to automate the system, and a hands-on approach by the operator was still desired because of the large number of research plots involved. First, the operator determines the amount of water to be required by a plot from the water budget. The operator enters the amount and event start time into an IBM-compatible computer. At the given time, the computer and software initiate a signal to a separate interface that allows power to open the solenoid valve. Water flows into the plot, and an electric pulse is sent to the remote register in the control building after every 380 l (100 gal) is applied. The interface box records and latches the pulse until the computer and software cycles to count the pulse and reset the latch. After the required number of pulses, the computer and software send a signal to the interface box to interrupt power to the solenoid, thereby shutting off the irrigation.

The automation system worked reasonably well for the few events in which it was used. Unfortunately lightning destroyed the computer I/O board, and further evaluation was not possible during the season. However, the interface box with its optically isolated controls, escaped damage. More observations of the automated system are required before its overall utility can be determined.

Visual observation of accumulated flows at the manhole can be made to the nearest 0.4 l (0.1 gal) which is well above the accuracy required for the plots. A four row plot 100 m (300 ft) long with an application amount of 25 mm (1 in) would require 15,240 l (3740 gal) of water. Shutting plots off based on counting a pulse of 380 l (100 gal) results in a considerable loss in flexibility. However, this could be somewhat compensated for during the multiple irrigation events of the season. Another possibility is for the computer to calculate a flowrate based on the time between pulses and then to project the additional time required to apply a given amount.

SECURITY CONSIDERATIONS

The drip irrigation system at Colby is within 2 km of the town, and there has been concern about vandalism. Most of the plot areas have the standard bed configuration which discourages driving through the plots because of the inherent roughness. However, the manholes are in straight lines on flat surfaces at the edge of the field. Each control assembly costs about 80 U.S. dollars (1990) in parts, excluding labor. The damage resulting from vehicle traffic over a line of manholes could cause a large monetary loss. In addition, it is likely that a season of information would be lost before the system could be fully repaired. Access control cables were erected parallel to the manholes around each plot area, leaving a narrow lane with enough width for passage of an all-terrain vehicle (ATV) between the cable and manholes. The access cables can be easily lowered for field operations such as planting and harvesting.

SUMMARY

Design criteria for a large multiple plot buried-line drip irrigation system have been presented. A portion of the 5.2 ha (12.8 acre) system has been operational for 2 years. The system has worked well, with relatively few problems. Many factors must be considered in designing and installing a system expressly for research use. Each irrigation system is inherently different because of characteristics such as site, water source, and intended use. However, this paper provides an approach to many of the design and installation considerations that are necessary to construct a drip irrigation system for research use.

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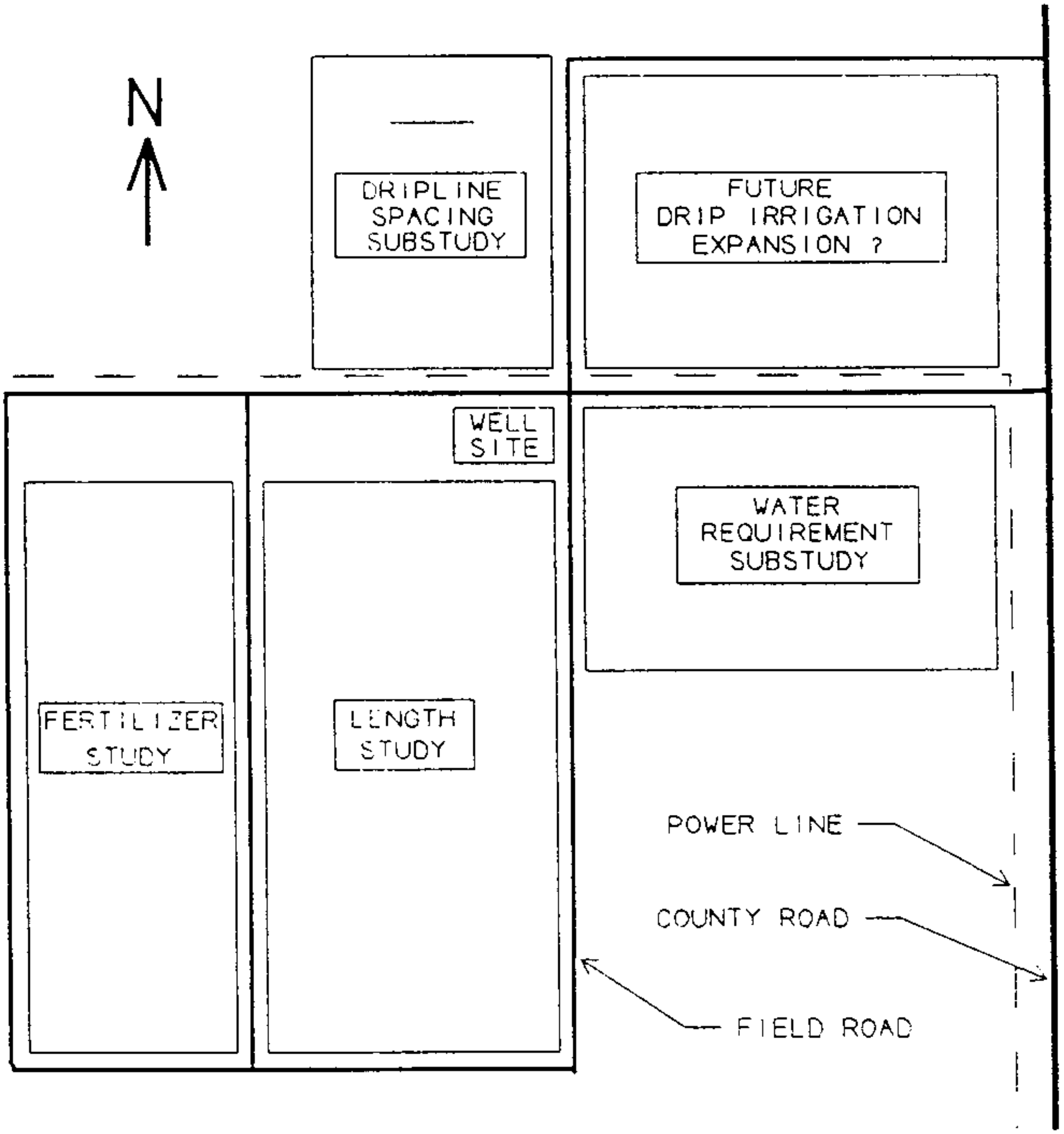

Figure 1. Site and field layout of the drip irrigation system at Colby, Kansas.

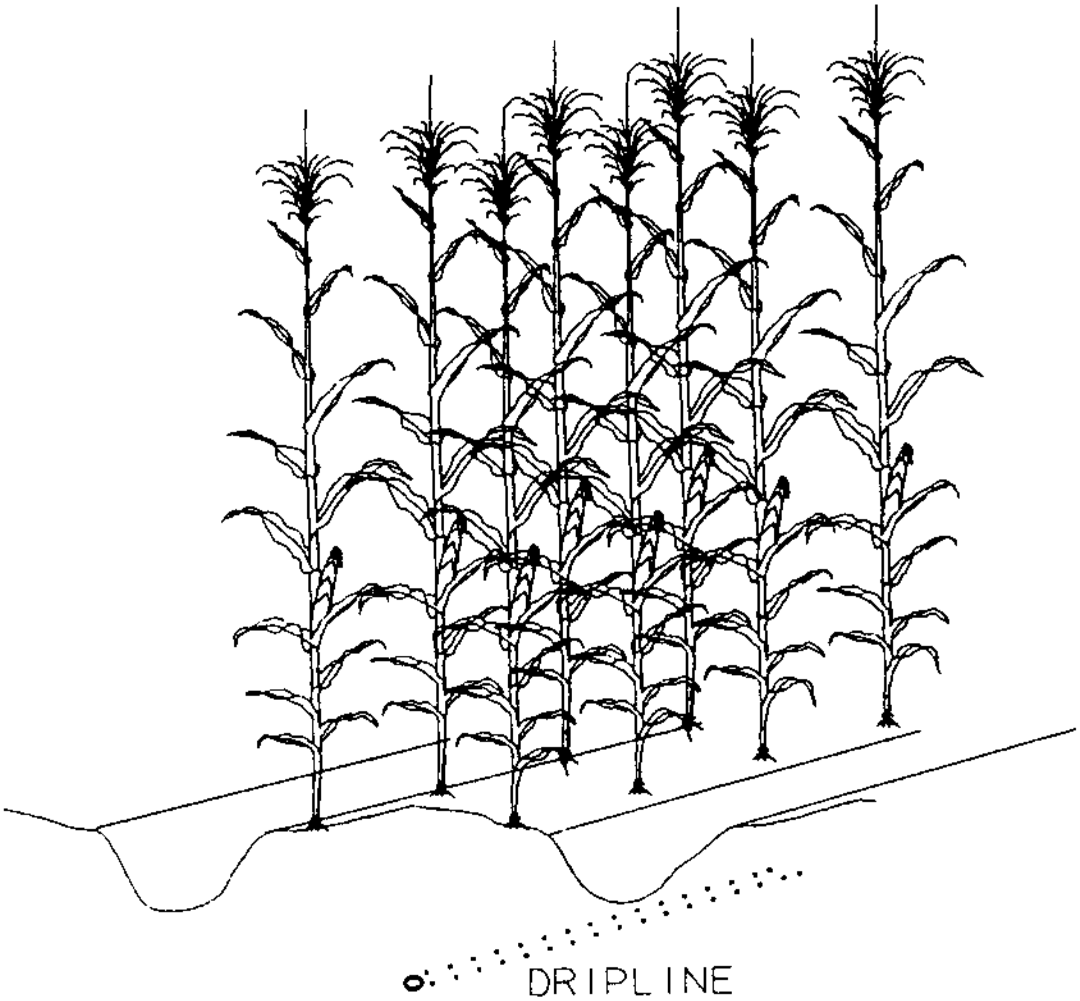

Figure 2. Physical arrangement of corn rows on permanent bed system in relation to the dripline.

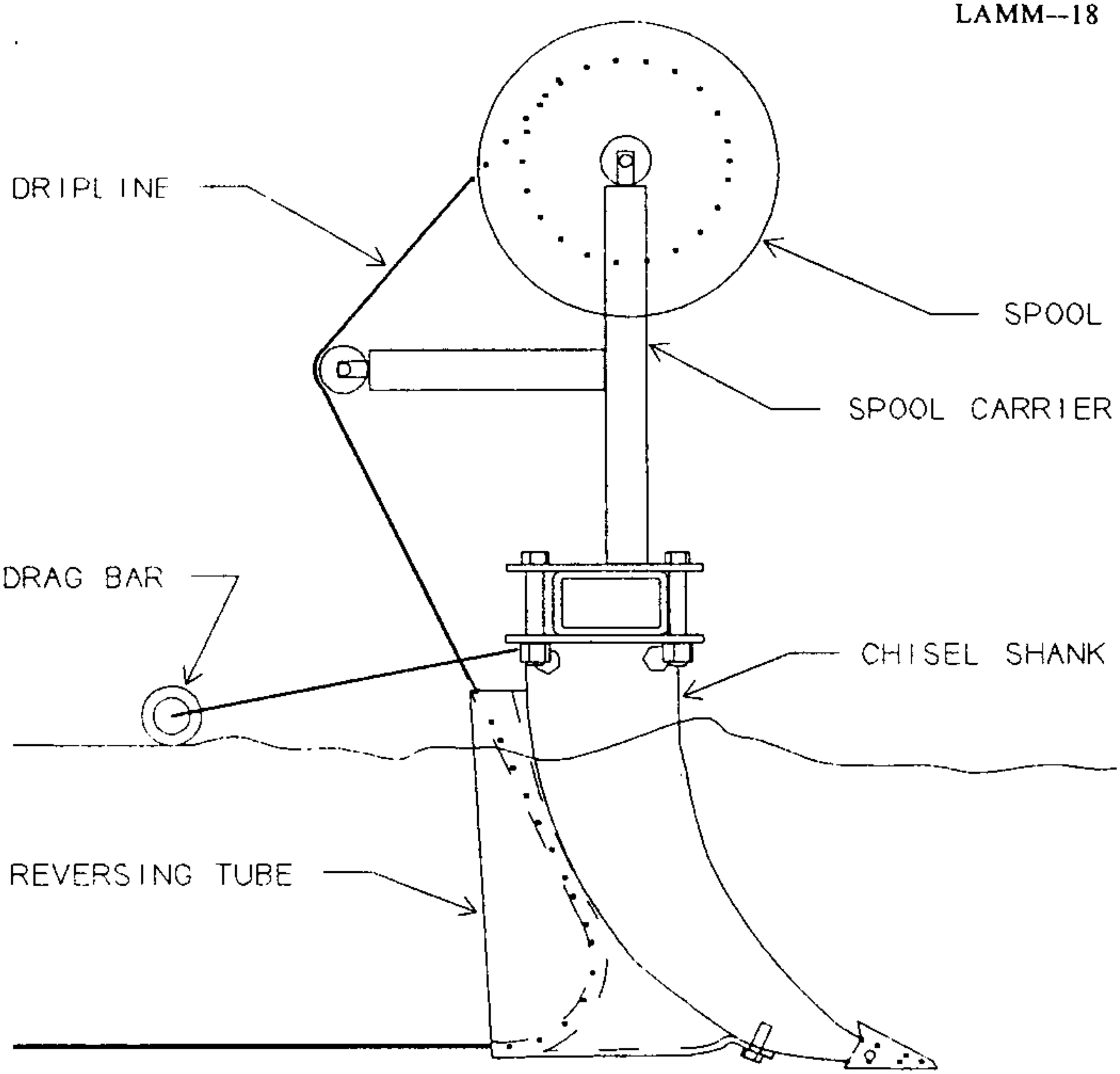

Figure 3. Schematic of the dripline installation implement.

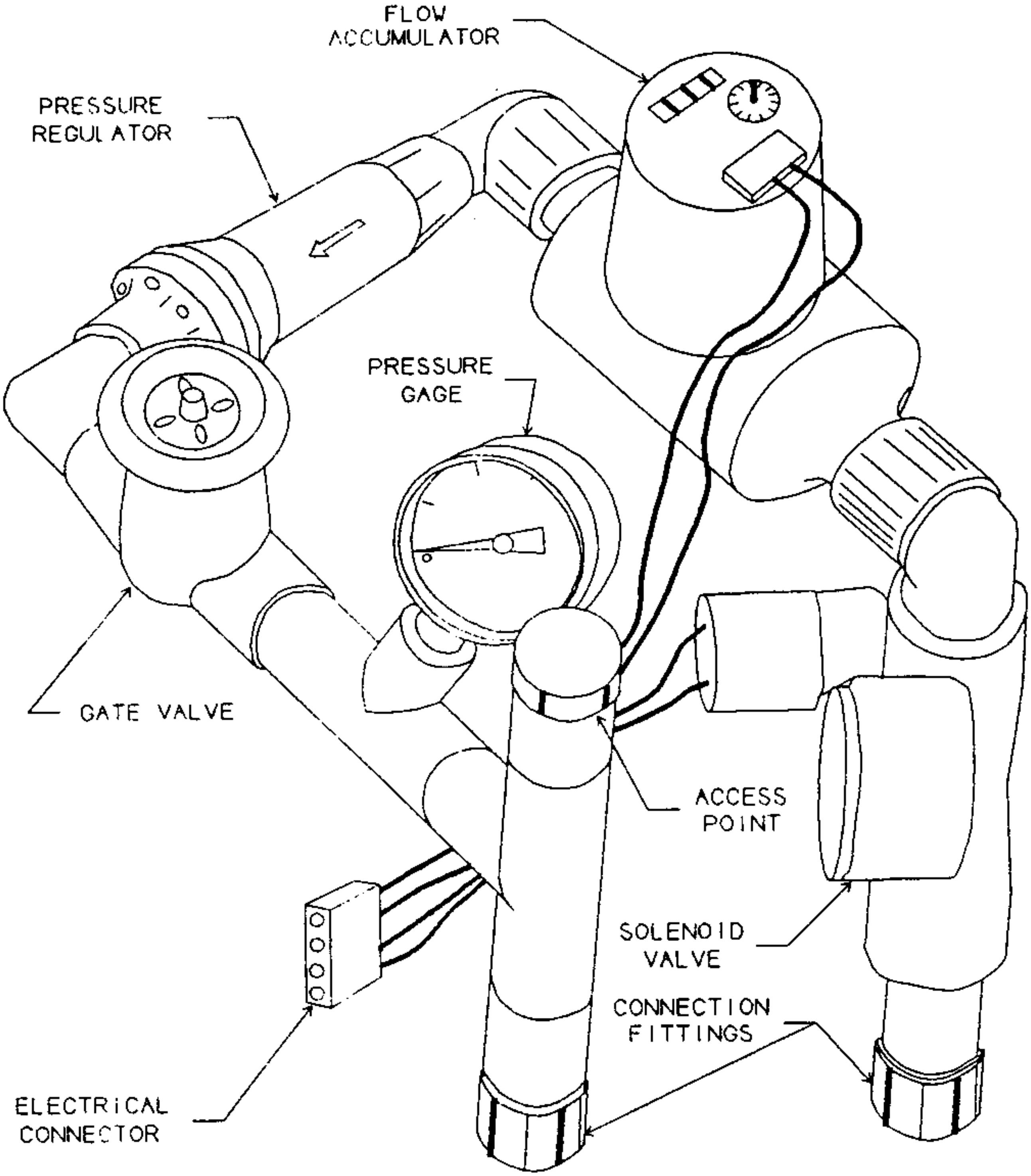

Figure 4. Control assembly used to control each subplot.

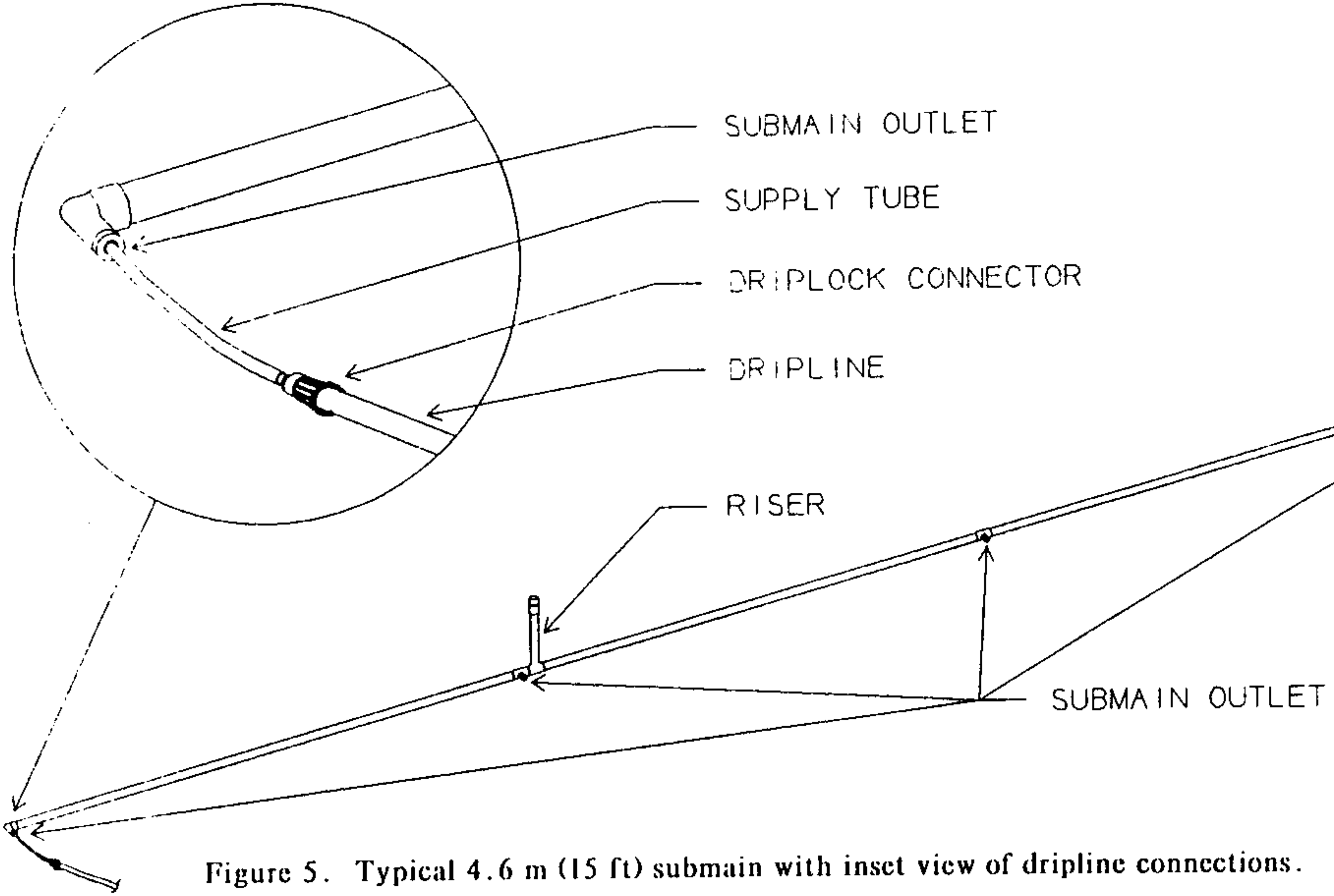

Figure 5. Typical 4.6 m (15 ft) submain with inset view of dripline connections.

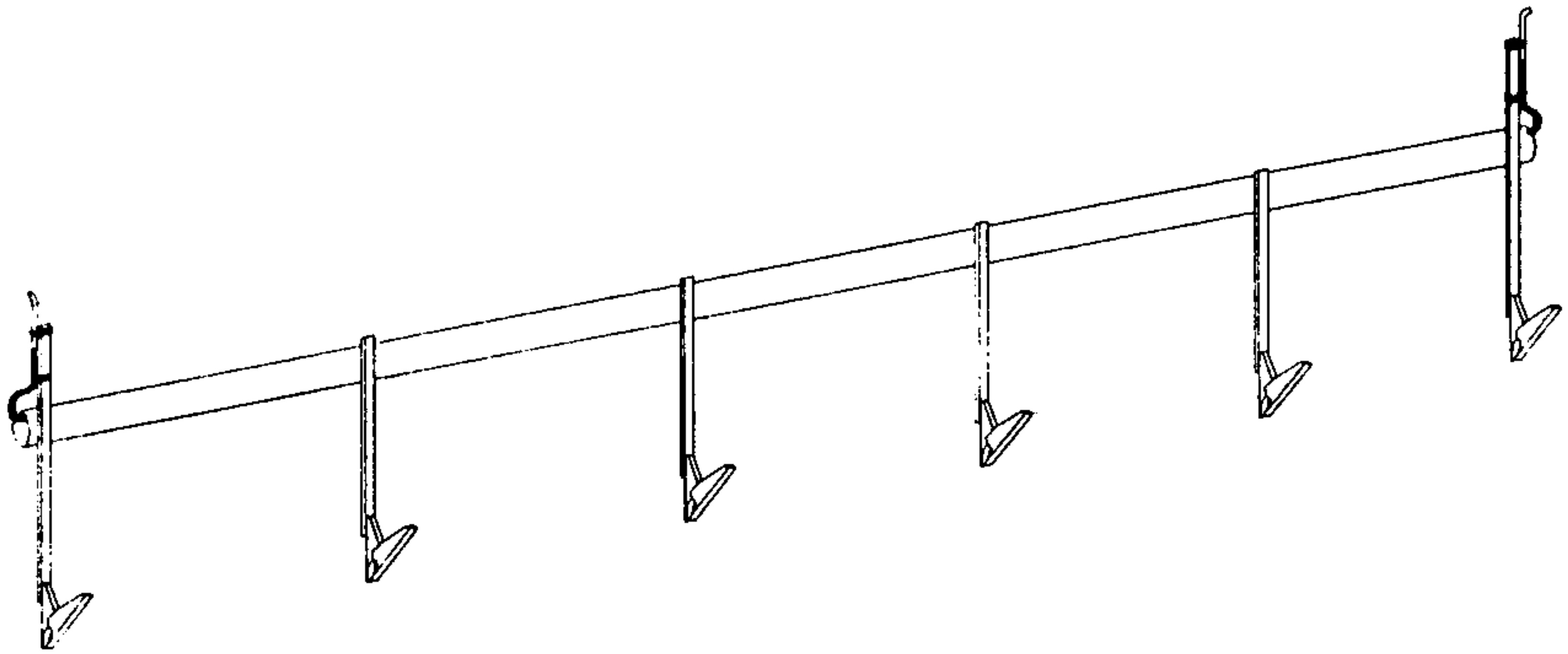

Figure 6. Submain leveler used to help ensure level installation of the submains.